Monitoring the Storm Tide of Hurricane Wilma in Southwestern Florida, October 2005

By Lars E. Soderqvist and Michael J. Byrne

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Conversion Factors, Datums, and Acronyms

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
atmosphere, standard (atm)	101.3	kilopascal (kPa)
bar	100	kilopascal (kPa)
inch of mercury at 60ºF (in Hg)	3.377	kilopascal (kPa)
pound-force per square inch (lbf/in^2)	6.895	kilopascal (kPa)
pound per square foot (lb/ft^2)	0.04788	kilopascal (kPa)
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)
pound per cubic foot (lb/ft^3)	16.02	kilogram per cubic meter (kg/m^3)

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88). Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Acronyms

BCB	Big Cypress Basin
COMPS	Coastal Ocean Monitoring and Observation System
EDT	Eastern Daylight Time
EST	Eastern Standard Time
GOES	Geostationary Operational Environmental Satellite
GPS	Global positioning system
SFWMD	South Florida Water Management District
USGS	U.S. Geological Survey

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Abstract

Temporary monitoring stations employing nonvented pressure transducers were used to augment an existing U.S. Geological Survey coastal monitoring network to document the inland water levels related to the storm tide of Hurricane Wilma on the southwestern coast of Florida. On October 22, 2005, an experimental network consisting of 30 temporary stations was deployed over 90 miles of coastline to record the magnitude, extent, and timing of hurricane storm tide and coastal flooding. Sensors were programmed to record time, temperature, and barometric or water pressure. Water pressure was adjusted for changes in barometric pressure and salinity, and then converted to feet of water above the sensor. Elevation surveys using optical levels were conducted to reference storm tide water-level data and high-water marks to the North American Vertical Datum of 1988 (NAVD 88). Storm tide water levels more than 5 feet above NAVD 88 were recorded by sensors at several locations along the southwestern Florida coast. Temporary storm tide monitoring stations used for this effort have demonstrated their value in: (1) furthering the understanding of storm tide by allowing the U.S. Geological Survey to extend the scope of data collection beyond that of existing networks, and (2) serving as backup data collection at existing monitoring stations by utilizing nearby structures that are more likely to survive a major hurricane.

Introduction

Residents in the southeastern United States were still recovering from Hurricanes Katrina and Rita when Hurricane Wilma appeared, the third category 5 storm of the 2005 Atlantic hurricane season and, at its peak, the most intense tropical cyclone ever recorded in the Atlantic Basin (fig. 1). The intensity of Wilma was reduced considerably by its travel over the Yucatán Peninsula on October 21-22, 2005, but reintensified into a category 3 storm as it moved into the Gulf of Mexico and approached Florida. Maximum sustained winds increased to 115 mi per hour and hurricane-force winds extended outward 85 mi from the center (Pasch and others, 2006). A storm surge of 9 to 17 ft above normal tide levels was predicted for the southwestern coast of Florida and areas south of the projected storm path.

On October 20, 2005, a team from the U.S. Geological Survey (USGS) in Ruston, Louisiana, was dispatched to Fort Myers, Florida, with enough pressure transducers (sensors) and housings to establish 30 temporary stations along the southwestern Florida coast where landfall was expected. Prior to team arrival, USGS employees in Fort Myers determined deployment locations for these stations based on preexisting structures, such as dock and bridge pilings. The monitored area extended from Boca Grande Pass, at the entrance to Charlotte Harbor, south to Everglades City at the northern edge of Everglades National Park. An existing USGS real-time coastal hydrologic

Figure 1. Path of Hurricane Wilma during October 2005 (modified from Pasch and others, 2006). Filled and open circles represent the approximate eye position of Hurricane Wilma, respectively, at midnight and noon UTC (Coordinated Universal Time) on the dates shown. Local time (Eastern Daylight Time) is UTC time minus 4 hours.

monitoring network extends from Everglades City south into Florida Bay and, therefore, was already in place to monitor storm tide in that region (fig. 2). Where possible, sites were positioned to create a transect from the coast to interior estuarine bays and rivers.

All temporary stations were installed by October 22, 2005. Less than 48 hours later the hurricane made landfall south of Marco Island, where the magnitude, extent, and timing of the storm tide were recorded by the sensors.

The temporary stations used for this effort and for Hurricane Rita have allowed the USGS to (1) extend the scope of data collection beyond that of existing networks, and (2) backup data collection at existing monitoring stations by utilizing nearby structures that are more likely to survive a major hurricane, such as bridge pilings. Data from this monitoring effort, conducted under severe conditions, can be used to improve the current understanding and prediction of storm tide.

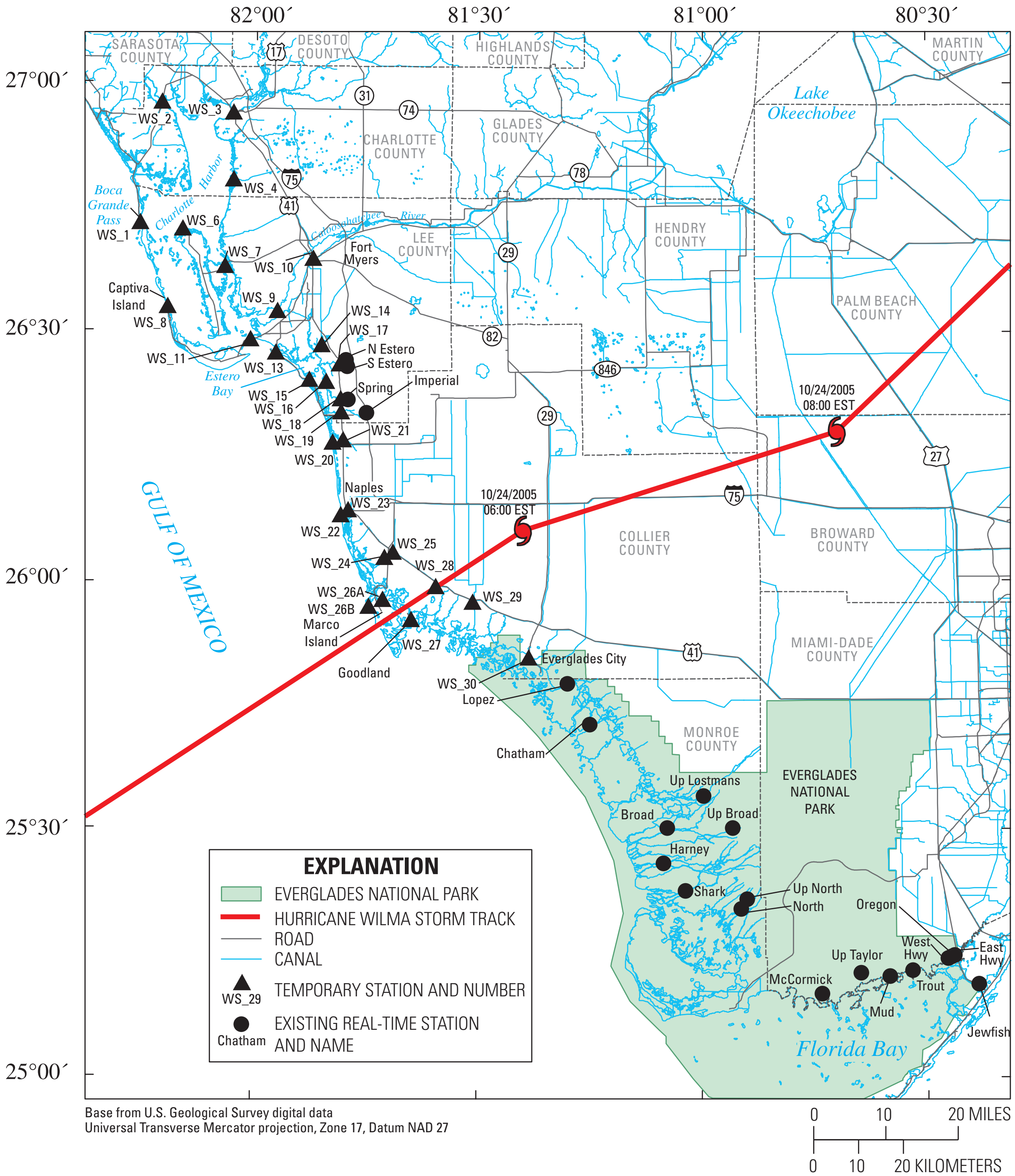

Figure 2. Temporary and real-time monitoring stations used in this study.

Purpose and Scope

This report documents the procedures used to collect storm tide data for Hurricane Wilma in southwestern Florida. Storm tide elevation data are presented for the 23 of 30 stations where storm tide was observed (arbitrary water-level data from the remaining 7 stations is made available but is not discussed). Data collected include date and time, temperature, and pressure (barometric and water), as well as all data used to adjust pressure data from inundated sensors to water-level elevation above NAVD 88. At one station where storm tide was substantial enough to leave a high-water mark, direct measurements of its elevation are compared to peak water levels measured at a nearby sensor. Storm tide data detected by the USGS real-time coastal monitoring stations in southwestern Everglades National Park and northeastern Florida Bay are also presented.

This report uses the term "storm tide" in place of "storm surge." As defined by the National Ocean and Atmospheric Administration, "storm tide" refers to the total water level above a datum generated by a storm. "Storm surge" refers to the component of the storm tide over and above the predicted astronomical tide (Jelesnianski and others, 1992). Additional information is available at: http://www.nhc.noaa.gov/HAW2/English/storm_surge.shtml and at http://www.asp.ucar.edu/colloquium/1988/Houston.jsp.

Previous Investigations

This study is preceded by a study of Hurricane Rita by McGee and others (2006a,b). The same sensors and housings developed by the USGS in Ruston, Louisiana, and used for Hurricane Rita were also used in this study. The deployment, recovery, and data processing procedures were also identical, with four exceptions: (1) elevation surveys relied on differential leveling from land-based survey benchmarks rather than global positioning system (GPS) surveying; (2) because the storm tide of Wilma was smaller than that of Rita, only one high-water mark (instead of seven) was established and surveyed to verify data from the sensors; (3) data from the sensors were not confirmed by tapedowns to the existing water surface during deployment or recovery; and (4) the term "storm tide" is used in place of "storm surge."

Acknowledgments

The authors wish to thank the USGS personnel for their dedication in making this monitoring effort possible, including Ben McGee and Burl Goree (Ruston, Louisiana), Kevin Hubbs and Ray Dupuis (Tampa, Florida), Gene Krupp, Sara Hammermeister, Craig Thompson, Jessica Flanigin, and Eduardo Patino (Fort Myers, Florida), Scott Prinos (Fort Lauderdale, Florida), and Robert Mason (Reston, Virginia). The authors would also like to thank Cliff Merz from the University of South Florida for providing data from the Coastal Ocean Monitoring and Observation System, as well as Tim Howard from the South Florida Water Management District Big Cypress Basin for providing data from their monitoring network.

Data Collection and Methods

The storm tide monitoring network consists of 21 real-time permanent stations and 30 temporary stations. Data collected at the permanent (real-time) sites include continuous (15-minute interval) measurements of stage. All raw data at the real-time sites were recorded by an electronic data logger and transmitted every 4 hours by way of the Geostationary Operational Environmental Satellite (GOES) into the database of the USGS Florida Integrated Science Center in Fort Lauderdale, Florida.

At the temporary sites, data collection included pressure transducer deployment and recovery, data corrections, high-water mark determination where possible, and elevation surveys. Although the network originally included 31 temporary stations, WS_5 was not deployed due to the lack of an available structure for installation. Of the remaining 30 stations, WS_12 was not surveyed in due to pier replacement following the passage of Wilma, and WS_1-4 and WS_6-7 were not leveled in due to a lack of storm tide.

Pressure Transducer Deployment and Retrieval

Pressure transducers (or sensors) were programmed prior to deployment to measure and record time, temperature, and pressure every 30 seconds during the storm and for several days after passage of the storm.

Figure 3. Water-level sensor deployed at WS_26A Marco Island Bayside.

Sensors were deployed in 1.5 × 18 in. metal pipes and strapped to permanent objects, such as piers and power poles. Water-level sensors were deployed at elevations considered susceptible to storm tide inundation and barometric-pressure sensors were deployed at elevations considered not susceptible (figs. 3 and 4, respectively). During deployments, reference marks, consisting of driven nails or chiseled lines in concrete were created near each water-level sensor, and the vertical distance from the reference mark to the sensor (offset) was recorded (fig. 5). All sensors were retrieved less than 4 days after Hurricane Wilma passed, and offsets were checked to verify that the sensors had not moved relative to the reference mark.

Data Corrections

Pressure data from inundated sensors were corrected for changes in barometric pressure using data from barometric-pressure sensors and the following formula:

$$P_w - P_b = P_c , \quad (1)$$

where

P_w is water pressure, in pounds per square inch;

P_b is barometric pressure, in pounds per square inch; and

P_c is corrected water pressure, in pounds per square inch.

Figure 4. Barometric-pressure sensor deployed at WS_19 Imperial River.

If a barometric-pressure sensor was not co-located with a water-level sensor, the data from the nearest barometric-pressure sensor was used to correct the water-level data. Water-level data from sensors also were corrected for salinity (water density) as:

$$(P_c \times 144) / D_w = H_w , \qquad (2)$$

where

144 is a conversion factor to compute pounds per square inch to pounds per cubic foot;

D_w is water density in pounds per cubic foot; and

H_w is water height above the transducer on the sensor, in feet.

Corrections for salinity were based upon the location of the sensor in proximity to the coast. In general, sensors located at the coast were categorized as saltwater (density of saltwater is 63.9887 lb/ft^3), and sensors located at estuarine bays and tributaries were categorized as brackish (density of brackish water is 63.0522 lb/ft^3).

High-Water Mark Determination

Historically, peak storm tide has been estimated using high-water marks created by flood waters. Identifying and qualifying high-water marks often is subjective. High-water marks are qualified as poor, good,

Figure 5. Water-level sensor deployment at WS_30 Everglades City.

or excellent depending upon the type of mark (such as debris, seed, mud, or stain) and whether the mark was created in a protected environment (such as the interior wall of a building) or unprotected environment (such as an exposed bridge piling or fence post).

Field crews searched for high-water marks in the vicinity of each water-level sensor during the retrieval process. Only one high-water mark was discovered, near WS_30 in a storage room at an Everglades National Park Ranger station, and was rated excellent. The lack of other high-water marks probably was due to the small size of the storm tide, lack of surfaces to which the marks might have adhered, and disturbance from wind and waves.

Elevation Surveys

Elevation surveys were conducted at all temporary stations with measurable storm tide (based on a preliminary analysis) to relate water-level data from inundated sensors, as well as the high-water mark, to NAVD 88. Traditional optical levels were run from nearby benchmarks to the reference mark, with all levels closing within ± 0.01 ft; benchmark information is provided in table 1. Adding the offset to the reference mark elevation provides the elevation of the sensor, which allows the arbitrary storm tide data to be referenced to NAVD 88. A brass disc survey monument was set in concrete near each storm tide station to provide a backup elevation in case a reference mark is destroyed during future storms.

Elevations at the USGS real-time monitoring stations at N. Estero River, S. Estero River, Spring Creek, and Imperial River were obtained through traditional optical levels run from nearby benchmarks. Elevations at the USGS real-time coastal monitoring stations in southwestern Everglades National Park and northeastern Florida Bay were obtained through GPS static surveys employing long duration observations, typically 48 hours, producing heights within 0.787 in. (2 cm) of the datum.

Table 1. Station name, type, location, and benchmark information.

[CERP, Comprehensive Everglades Restoration Program; CGS, Coast and Geodetic Survey; GPS, Global Positioning System; FL DOT, Florida Department of Transportation; NA, not applicable; NOS, National Oceanic Survey; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; CR, County Road; SR, State Road; US, U.S. Highway; ENP, Everglades National Park]

USGS station name	Abbreviated station name	Station type	Latitude	Longitude	Benchmark
Lopez River	Lopez	Permanent (real time)	25° 47' 28.3"	81° 17' 58.8"	STATIC GPS SURVEY
Chatham River	Chatham	Permanent (real time)	25° 42' 33.1"	81° 14' 59.7"	STATIC GPS SURVEY
UPS Lostmans	Up Lostmans	Permanent (real time)	25° 33' 57.1"	80° 59' 48.7"	STATIC GPS SURVEY
Broad River Cutoff	Broad	Permanent (real time)	25° 30' 05.3"	81° 04' 37.5"	STATIC GPS SURVEY
UPS Broad River	Up Broad	Permanent (real time)	25° 30' 04.7"	80° 55' 55.9"	STATIC GPS SURVEY
Shark River	Shark	Permanent (real time)	25° 22' 29.8"	81° 02' 12.1"	STATIC GPS SURVEY
Harney River	Harney	Permanent (real time)	25° 25' 49.0"	81° 05' 09.0"	STATIC GPS SURVEY
North River	North	Permanent (real time)	25° 20' 19.2"	80° 54' 47.8"	STATIC GPS SURVEY
UPS North River	Up North	Permanent (real time)	25° 21' 30.3"	80° 54' 01.0"	STATIC GPS SURVEY
East Highway Creek	E Hwy	Permanent (real time)	25° 14' 42.0"	80° 26' 27.6"	STATIC GPS SURVEY
Jewfish Creek	Jewfish	Permanent (real time)	25° 11' 13.2"	80° 23' 13.2"	STATIC GPS SURVEY
Trout Creek	Trout	Permanent (real time)	25° 12' 53.0"	80° 32' 01.0"	STATIC GPS SURVEY
McCormick Creek	McCormick	Permanent (real time)	25° 10' 04.8"	80° 44' 02.4"	STATIC GPS SURVEY
Mud Creek	Mud	Permanent (real time)	25° 12' 10.8"	80° 35' 02.4"	STATIC GPS SURVEY
Oregon Creek	Oregon	Permanent (real time)	25° 14' 20.4"	80° 27' 18.0"	STATIC GPS SURVEY
Upstream Taylor	Up Taylor	Permanent (real time)	25° 12' 03.6"	80° 38' 52.8"	STATIC GPS SURVEY
West Highway Creek	W Hwy	Permanent (real time)	25° 14' 31.2"	80° 26' 52.8"	STATIC GPS SURVEY
N. Branch Estero	N Estero	Permanent (real time)	26° 26' 30.0"	81° 47' 45.0"	Wilson Miller Benchmark 1988 (private)
S. Branch Estero	S Estero	Permanent (real time)	26° 25' 43.0"	81° 47' 36.0"	FL DOT Benchmark 175 Y11
Spring Creek	Spring	Permanent (real time)	26° 21' 42.0"	81° 47' 27.0"	FL DOT Benchmark R-244
Imperial River	Imperial	Permanent (real time)	26° 20' 07.0"	81° 44' 59.0"	FL DOT Benchmark I-75 F11
Charlotte Harbor at Boca Grand Pass	WS_1	Temporary	26° 43' 06.0"	82° 15' 31.9"	NA
Myakka River at El Jobean	WS_2	Temporary	26° 57' 40.0"	82° 12' 44.1"	NA
Peace River at Punta Gorda	WS_3	Temporary	26° 56' 25.6"	82° 03' 05.8"	NA
Charlotte Harbor at Pirate Harbor	WS_4	Temporary	26° 48' 21.2"	82° 03' 02.6"	NA
Charlotte Harbor at Bokeelia	WS_6	Temporary	26° 42' 22.3"	82° 09' 49.3"	NA
Matlacha Pass at SR-78	WS_7	Temporary	26° 37' 54.6"	82° 04' 06.4"	NA

Table 1. (Continued) Station name, type, location, and benchmark information.

[CERP, Comprehensive Everglades Restoriation Program; CGS, Coast and Geodetic Survey; GPS, Global Positioning System; FL DOT, Florida Department of Transportation; NA, not applicable; NOS, National Oceanic Survey; SFWMD, South Florida Water Management District; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; CR, County Road; SR, State Road; US, U.S. Highway; ENP, Everglades National Park]

USGS station name	Abbreviated station name	Station type	Latitude	Longitude	Benchmark
Captiva Islands at South Seas	WS_8	Temporary	26° 33' 00.1"	82° 11' 45.6"	MP of USGS ground-water monitoring well L-5766
Caloosahatchee River at Redfish Point	WS_9	Temporary	26° 32' 29.8"	81° 57' 01.9"	TKW Benchmark (private)
Caloosahatchee River at Ft. Myers city ramp	WS_10	Temporary	26° 38' 49.8"	81° 52' 15.5"	NOS Benchmark 5520 B
San Carlos Bay at Punta Rassa boat ramp	WS_11	Temporary	26° 29' 03.9"	82° 00' 38.1"	NOS Benchmark 5391 G
Ft. Myers Beach at pier	WS_12	Temporary	26° 27' 30.1"	81° 57' 11.9"	NA
Ft. Myers Beach at Matanzas Pass	WS_13	Temporary	26° 27' 30.1"	81° 57' 11.9"	FL DOT Benchmark 5366 G
Mullock Creek Marina	WS_14	Temporary	26° 28' 24.9"	81° 51' 05.1"	MP of USGS ground-water monitoring well L-735
Big Carlos Pass	WS_15	Temporary	26° 24' 13.6"	81° 52' 40.8"	CGS Benchmark Z 246
Estero Bay at Coconut Point Marine	WS_16	Temporary	26° 23' 59.7"	81° 50' 25.3"	CGS Benchmark T 244
Estero River at US-41	WS_17	Temporary	26° 26' 06.3"	81° 48' 38.5"	FL DOT Benchmark 1099
Spring Creek at US-41	WS_18	Temporary	26° 21' 54.0"	81° 48' 28.7"	FL DOT Benchmark 64
Imperial River at US-41	WS_19	Temporary	26° 20' 20.3"	81° 48' 24.9"	FL DOT Benchmark 59
Delnor-Wiggins State Park	WS_20	Temporary	26° 16' 40.5"	81° 49' 30.6"	USACE Benchmark WP 10
Cocahatchee River at US-41	WS_21	Temporary	26° 16' 57.8"	81° 48' 07.2"	NOAA Driven rod Benchmark K416
Naples Municipal pier	WS_22	Temporary	26° 07' 54.2"	81° 48' 23.2"	NOS Benchmark No 8 1974
Naples Bay at US-41 Gordon River bridge	WS_23	Temporary	26° 08' 30.5"	81° 47' 25.0"	Tidal Benchmark BMT B48
KOA Campground at Henderson Creek	WS_24	Temporary	26° 02' 45.8"	81° 42' 30.4"	SFWMD Benchmark at Tower Rd station
Henderson Creek at US-41	WS_25	Temporary	26° 03' 25.7"	81° 41' 22.6"	SFWMD Benchmark BCB HC3
Marco Island Bayside at Marco Island Yacht Club	WS_26A	Temporary	25° 57' 42.4"	81° 42' 43.6"	FL DOT Benchmark COL 16
Marco Island Gulfside at Tigertail Beach	WS_26B	Temporary	25° 56' 52.9"	81° 44' 36.3"	FL DOT Benchmark COL 14
Goodland at CR-92 bridge	WS_27	Temporary	25° 55' 18.0"	81° 38' 54.5"	NOS Benchmark 4979 A Tidal
Blackwater River at Seminole-Collier State Park	WS_28	Temporary	25° 59' 17.2"	81° 35' 38.8"	US CGS Benchmark S250 1965
Faka-Union Canal at Port of the Isles	WS_29	Temporary	25° 57' 24.3"	81° 30' 41.5"	CERP Benchmark M 527 2001
Everglades City at ENP ranger station	WS_30	Temporary	25° 50' 42.4"	81° 23' 11.0"	NOS Benchmark COL1 1978

Hurricane Wilma Storm Tide Data

Measurable storm tide occurred at all temporary stations from Captiva Island south to Everglades City (table 2, figs. 6 and 7). Storm tide was also detected at all USGS real-time coastal monitoring stations in southwestern Everglades National Park and northeastern Florida Bay (fig. 8). A storm tide of about 1 ft was observed at the northernmost stations in the Caloosahatchee River and Estero Bay. A storm tide of 1.5 to 2.0 ft was observed at bridges along Highway U.S. 41 over tributaries to Estero Bay. The highest storm tide occurred at stations directly south of Marco Island (where Hurricane Wilma made landfall), with a maximum storm tide of 5.67 ± 0.5 ft above NAVD 88 recorded at Everglades City (WS_30). Storm tide was 4 to 5 ft at major coastal rivers along the southwestern coast of Everglades National Park, decreasing to 1 to 2 ft

Table 2. Storm tide and water density data.

[EST, Eastern Standard Time; mm/dd/yy, month, day, year; NAVD 88, North American Vertical Datum of 1988; NA, Not Applicable]

Abbreviated station name	Maximum recorded water level feet NAVD 1988	Date of maximum recorded water level (mm/dd/yy)	Time (EST) of maximum recorded water level	Water density	Barometric pressure sensor station
Lopez	3.52	10/24/05	1130	NA	NA
Chatham	4.88	10/24/05	0830-0845	NA	NA
Up Lostmans	1.90	10/24/05	2130-2245	NA	NA
Broad	1.76	10/24/05	1330	NA	NA
Up Broad	1.23	10/25/05	1245	NA	NA
Shark	4.17	10/24/05	1030-1045	NA	NA
Harney	5.06	10/24/05	1015	NA	NA
North	1.12	10/24/05	1815	NA	NA
Up North	0.70	10/25/05	0430-0500	NA	NA
E Hwy	2.62	10/24/05	1815-1845	NA	NA
Jewfish	0.76	10/24/05	1745	NA	NA
Trout	2.87	10/24/05	0645	NA	NA
McCormick	3.53	10/24/05	0730	NA	NA
Mud	3.37	10/24/05	0615	NA	NA
Oregon	2.35	10/24/05	1845	NA	NA
Up Taylor	1.83	10/24/05	0745	NA	NA
W Hwy	2.59	10/24/05	1845	NA	NA
N Estero	11.34	10/24/05	1600	NA	NA
S Estero	5.70	10/24/05	0945	NA	NA
Spring	8.52	10/24/05	1430	NA	NA
Imperial	9.03	10/24/05	2200	NA	NA
WS_1	NA	NA	NA	Seawater	WS_1
WS_2	NA	NA	NA	Seawater	WS_3
WS_3	NA	NA	NA	Seawater	WS_3
WS_4	NA	NA	NA	Seawater	WS_4
WS_6	NA	NA	NA	Seawater	WS_6
WS_7	NA	NA	NA	Seawater	WS_6
WS_8	2.35	10/24/05	0315	Seawater	WS_8
WS_9	1.63	10/24/05	0712	Brackish	WS_9
WS_10	1.02	10/24/05	0436	Brackish	WS_9
WS_11	0.97	10/24/05	1225	Brackish	WS_9
WS_12	NA	NA	NA	Seawater	WS_15
WS_13	1.01	10/24/05	1227	Seawater	WS_15

Table 2. (Continued) Storm tide and water density data.

[EST, Eastern Standard Time; mm/dd/yy, month, day, year; NAVD 88, North American Vertical Datum of 1988; NA, not applicable]

Abbreviated station name	Maximum recorded water level feet NAVD 1988	Date of maximum recorded water level (mm/dd/yy)	Time (EST) of maximum recorded water level	Water density	Barometric pressure sensor station
WS_14	0.74	10/24/05	0313	Brackish	WS_14
WS_15	1.10	10/24/05	1301	Seawater	WS_15
WS_16	0.97	10/24/05	1255	Brackish	WS_15
WS_17	1.57	10/24/05	1428	Brackish	WS_17
WS_18	1.58	10/24/05	1557	Brackish	WS_18
WS_19	1.90	10/24/05	0843	Brackish	WS_19
WS_20	1.97	10/24/05	1238	Seawater	WS_20
WS_21	2.44	10/24/05	1240	Brackish	WS_20
WS_22	5.84	10/24/05	1120	Seawater	WS_22
WS_23	2.20	10/24/05	1154	Brackish	WS_22
WS_24	2.19	10/24/05	1226	Brackish	WS_24
WS_25	2.18	10/24/05	1235	Brackish	WS_24
WS_26A	3.22	10/24/05	0730	Seawater	WS_26B
WS_26B	4.79	10/24/05	0620	Seawater	WS_26B
WS_27	4.93	10/24/05	0524	Seawater	WS_27
WS_28	1.60	10/24/05	1355	Brackish	WS_29
WS_29	2.39	10/24/05	1230	Brackish	WS_29
WS_30	5.67	10/24/05	0812	Seawater	WS_29

above NAVD 88 as the storm tide traveled inland. Storm tide of about 3 ft was measured along the coastal creeks of northeastern Florida Bay.

The maximum recorded water levels occurred at N. Estero River, Spring Creek, and Imperial River (fig. 6 and table 2). These permanent stations are located on tributaries to Estero Bay upstream from tidal effects under normal conditions. The magnitude of the water levels observed was influenced by the elevation of the streams at that point. Water levels increased sharply at all three stations (fig. 9), with the smallest increase of 2.79 ft occurring at Spring Creek and the greatest increase of 4.64 ft occurring at N. Estero River. Water levels in these streams increase rapidly during significant rain events, as occurred during the passing of Hurricane Wilma. The maximum water levels are likely more a function of flooding and stream elevations than storm tide. A similar increase in water levels was observed at S. Estero River (fig. 6 and table 2).

The reference mark at site WS_30 was lost prior to the elevation survey due to construction activity at the site, so its elevation had to be estimated based on photographs taken at the time of deployment. The maximum storm tide recorded at WS_30, however, agreed well with the 5.62-ft elevation of the high-water mark (rated excellent) found near the station (fig. 10).

Data from WS_25 agreed well with data from the South Florida Water Management District BCB Hendersen Creek monitoring station located 10 ft downstream from the US-41 bridge (fig. 11). Data from WS_15 agreed well with data from the University of South Florida Coastal Ocean Monitoring and Observation System (COMPS) Big Carlos Pass station located about 800 ft away near the center of the pass (fig. 12). The increased variability in the data from the temporary station in comparison to the COMPS station is due to the shorter data collection interval (30 seconds, compared to 6 minutes) at the temporary station, and because the COMPS station has a stilling well that substantially dampened the wave action during the storm. In addition, the COMPS water-level data represent a mean value of 3-minute data collected at 1-second intervals.

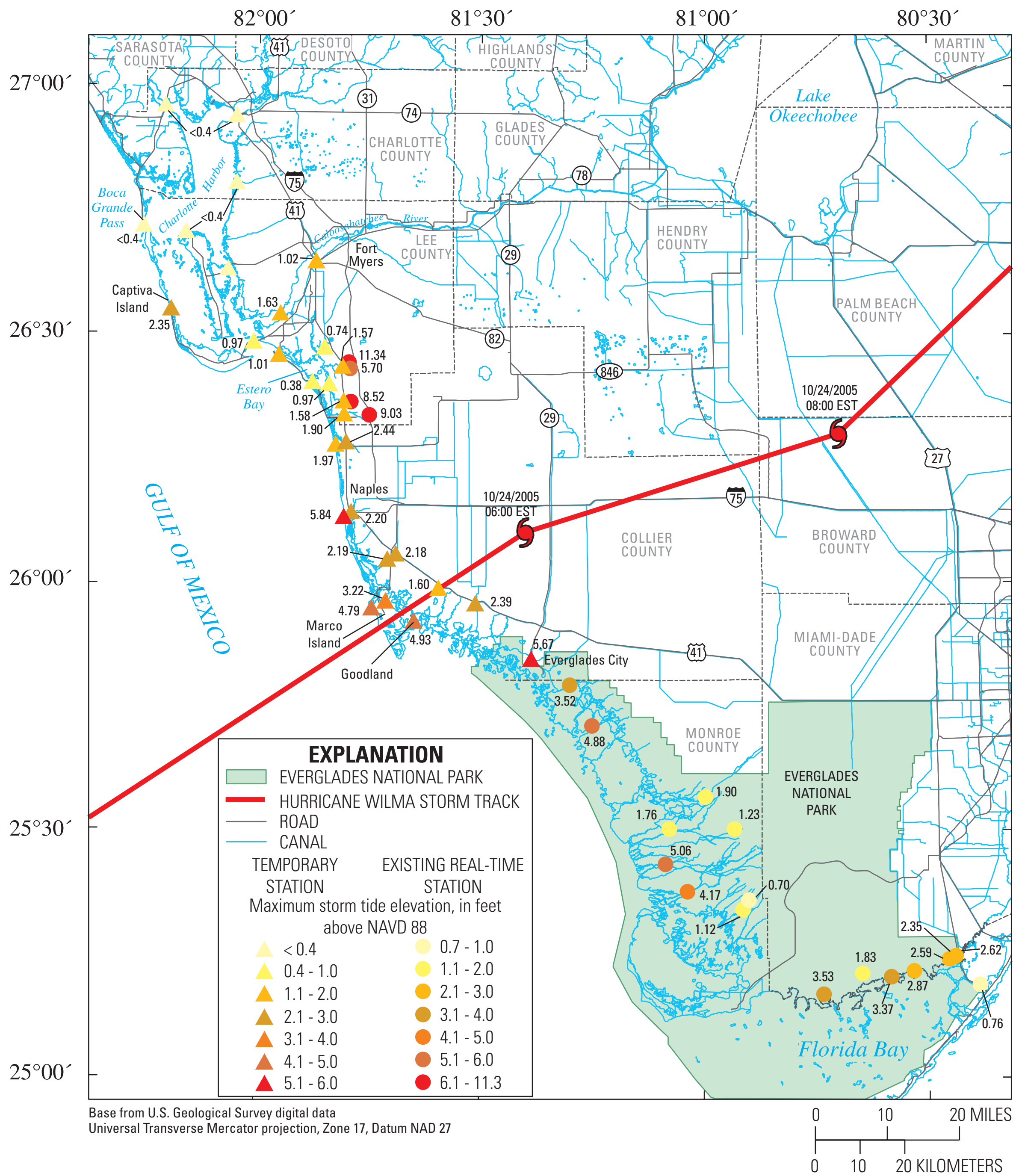

Figure 6. Storm tide measured at temporary and real-time monitoring stations.

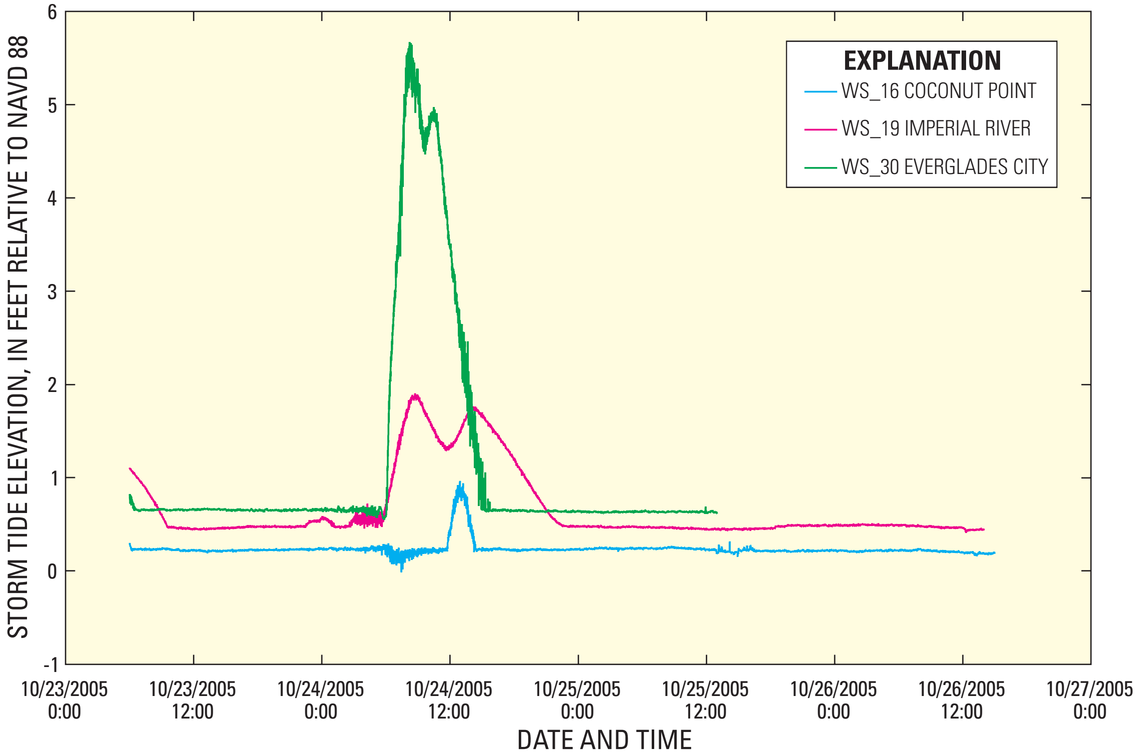

Figure 7. Hurricane Wilma storm tide elevations at selected temporary stations.

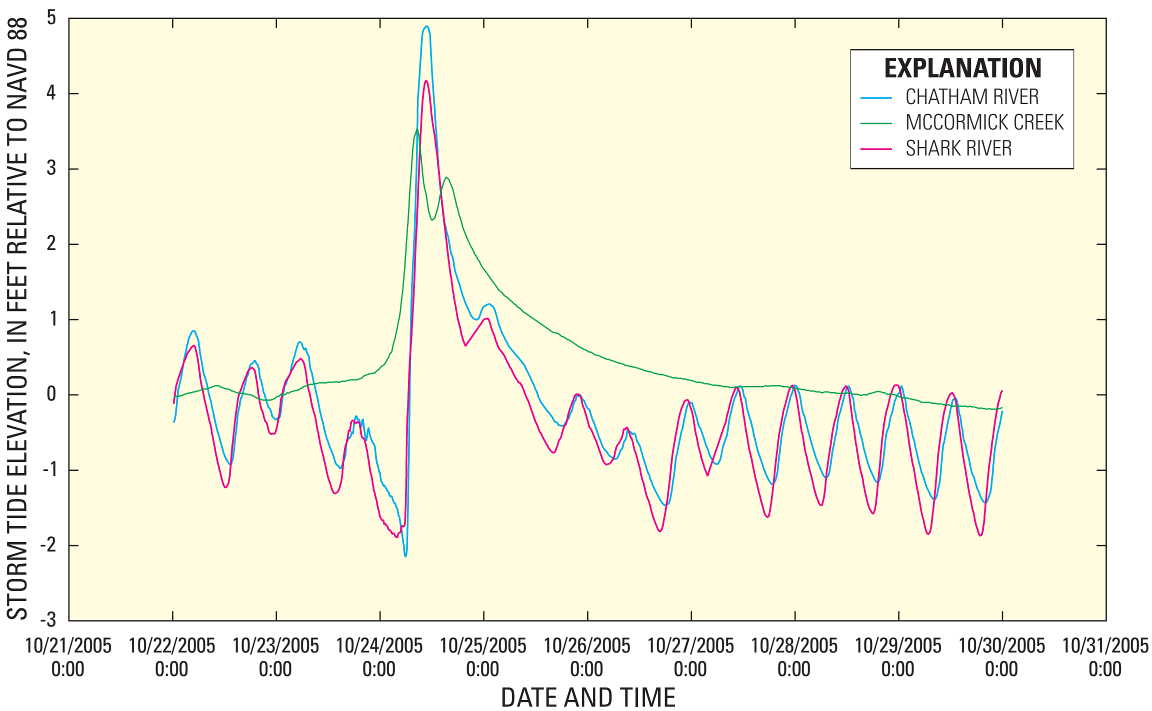

Figure 8. Hurricane Wilma storm tide elevations at selected real-time stations in Everglades National Park.

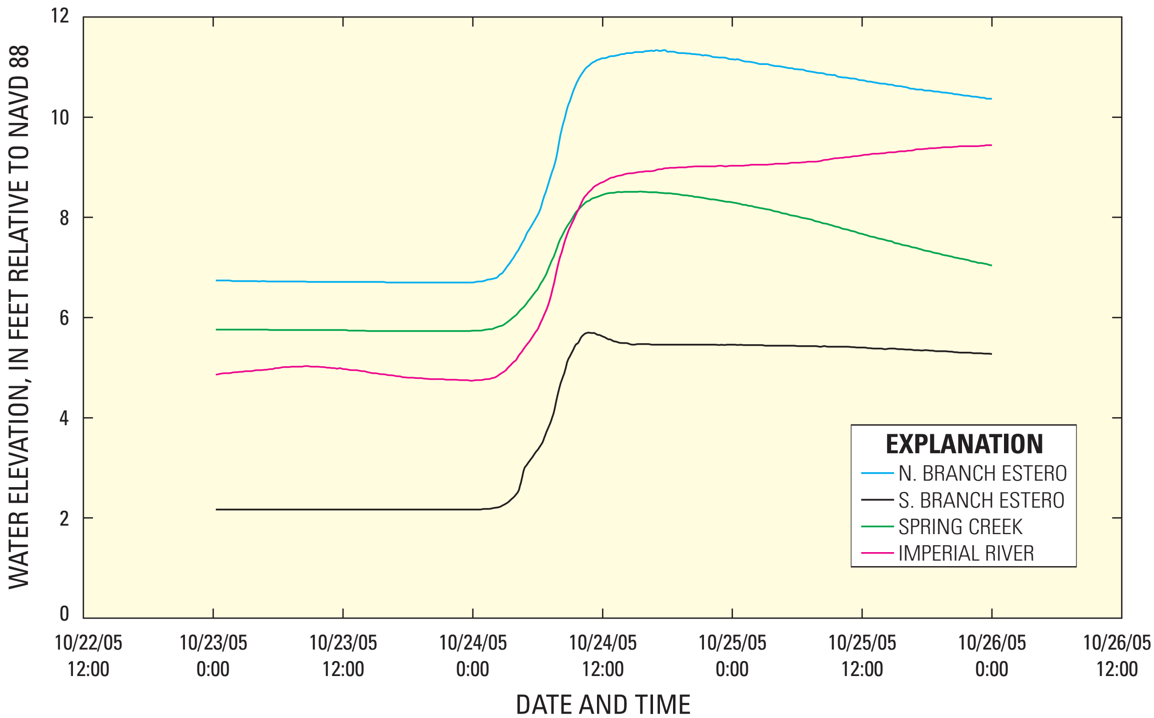

Figure 9. Water elevations at selected inland real-time stations.

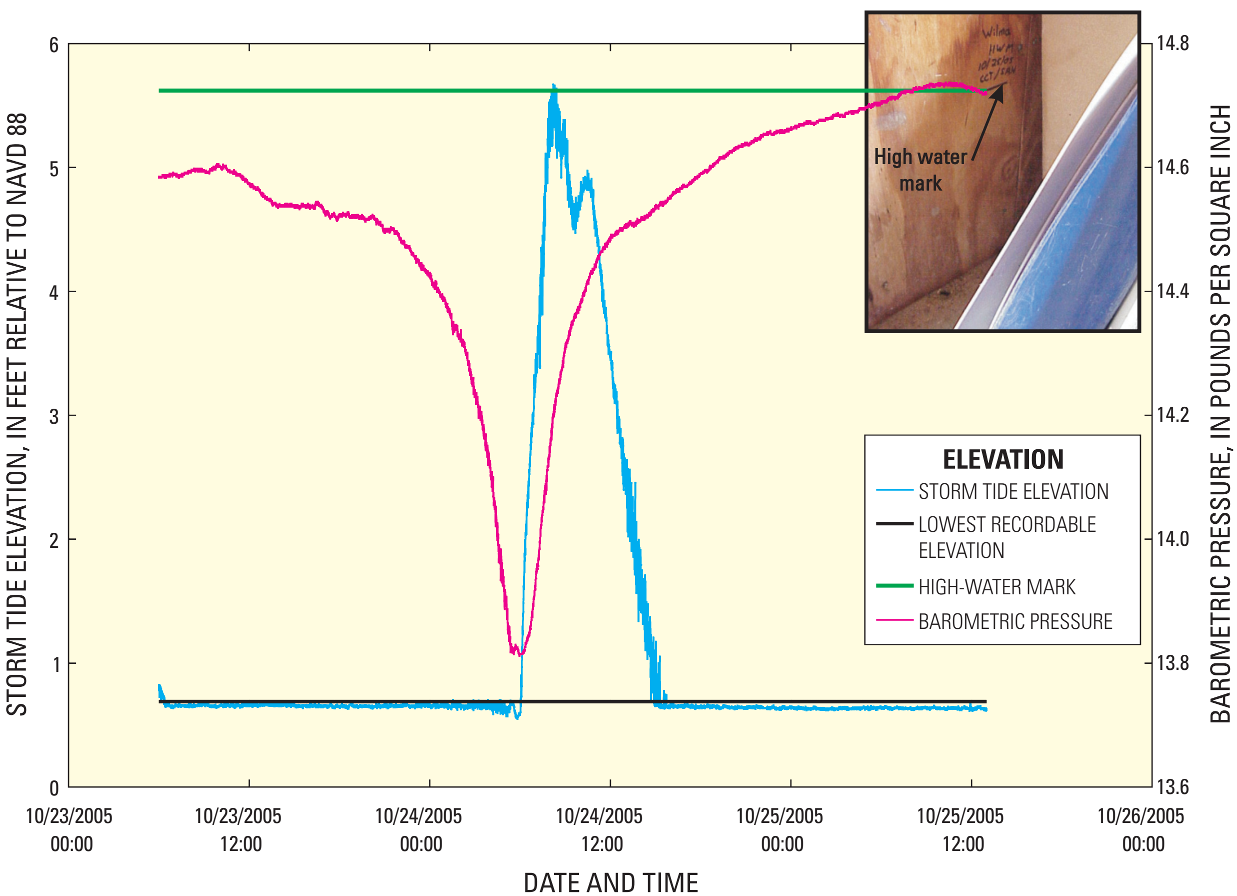

Figure 10. Hurricane Wilma storm tide elevations at WS_30 Everglades City, including high-water mark.

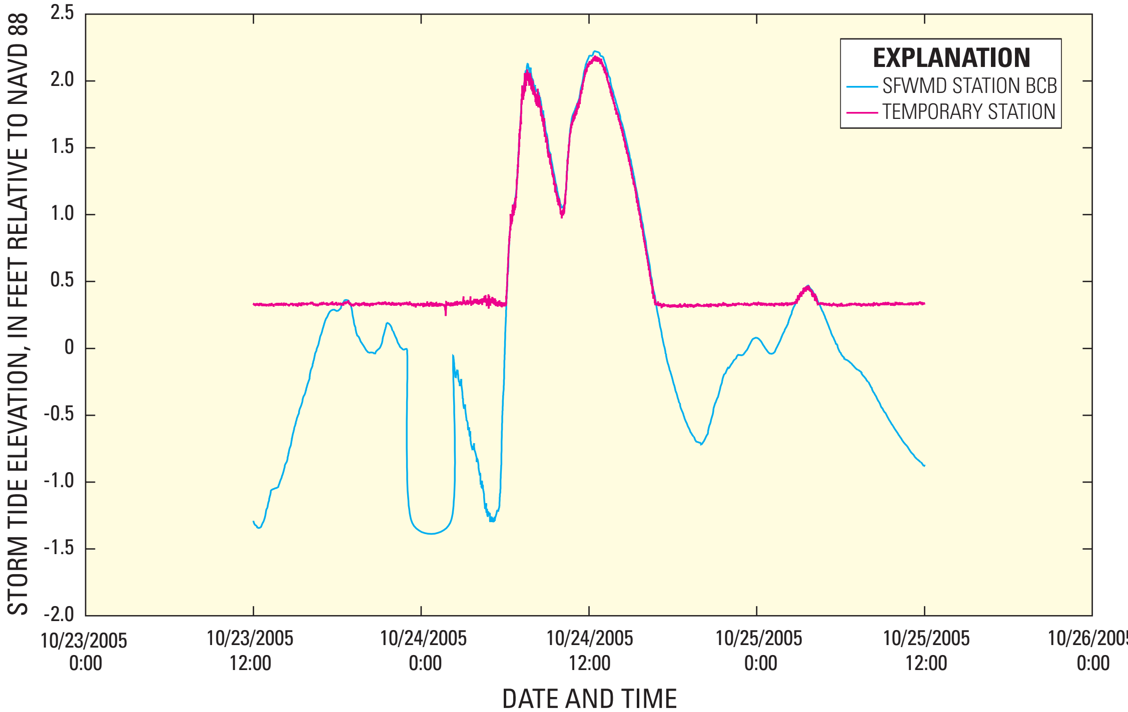

Figure 11. Comparison of Hurricane Wilma storm tide elevations at Hendersen Creek, as measured by South Florida Water Management District station BCB and U.S. Geological Survey temporary station WS_25. The BCB data were obtained from the DBHYDRO database.

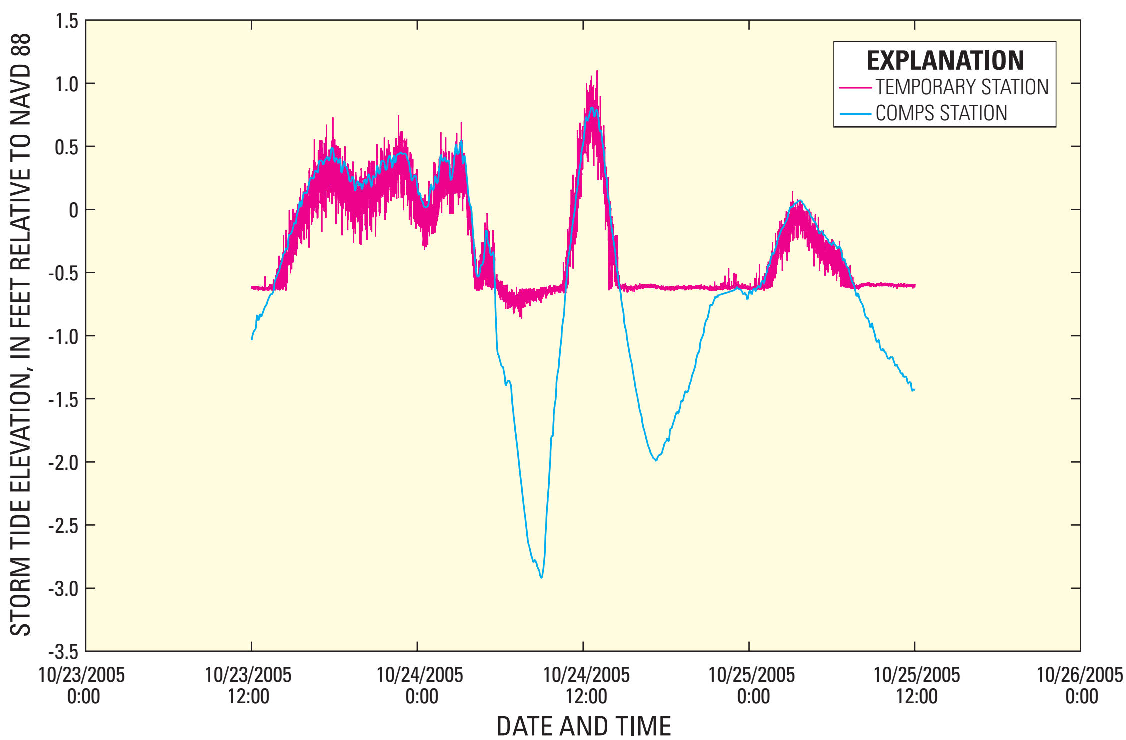

Figure 12. Comparison of Hurricane Wilma storm tide elevations at Big Carlos Pass, as measured by the University of South Florida COMPS station and U.S. Geological Survey temporary station WS_15. Data for the COMPS station are from University of South Florida Department of Marine Science (undated).

Substantial water-level drawdown is evident in the data from both the South Florida Water Management District BCB and University of South Florida COMPS stations prior to the arrival of the storm tide, but is minimal in data collected from neighboring temporary stations. As a hurricane makes landfall, water levels are typically lower along the shoreline reach with offshore winds and higher along the shoreline reach with onshore winds. This occurs because water is pushed seaward along the “offshore-wind” reach and landward along the “onshore-wind” reach. To accurately capture the drawdown, it is necessary to deploy the temporary stations as low as possible.

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Appendix—Hurricane Wilma Storm Tide Data Files, October 2005
(link accessible from web)

All data collected for this study from the temporary stations are presented as text files. All temporary stations recorded 30-second data. Data presented include date and time, water-level and barometric sensor pressure in pounds per square inch (PSI), arbitrary water elevation in feet, storm-tide water elevation in feet relative to NAVD 88, and lowest recordable water elevation in feet relative to NAVD 88. The lowest recordable water elevation was set to 0.05 ft above the elevation of the water-level sensor. Also presented are all data used to adjust pressure data from inundated sensors to storm-tide elevation above NAVD 88.

All data collected for this study from the real-time permanent stations are also presented. Permanent (real-time) stations recorded 15-minute data. Data presented includes date and time, and storm-tide water elevation relative to NAVD 88. Data were pulled from the USGS database as computed unit-value data.

Time-series graphs for all stations presented in this report (temporary and real-time) are also presented.